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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

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INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Mark David	Parsons	Clifton, VA
Robert Mack	Cothren	Walnut Creek, CA
John Scott	Birbeck	Farmington, UT

[X] *Additional inventors are being named on the* 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

A SYSTEM AND METHOD FOR HELPING TO DETERMINE THE CONDITION OF ABNORMAL TISSUE

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[X] Firm *or* Individual Name	TAROLLI, SUNDHEIM, COVELL, TUMMINO & SZABO				
Address	1111 Leader Building				
Address	526 Superior Avenue				
City	Cleveland	State	OH	ZIP	44114-1400
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[X] Other (specify) 12 claims (6 pages); 1 Abstract

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Respectfully submitted,

SIGNATURE [signature]

Date 10/21/98

TYPED or PRINTED NAME Gary J. Pitzer

REGISTRATION NO. *(if appropriate)* 39,334

TELEPHONE 216-621-2234

Docket Number: TMI-4111

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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Additional Page

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Docket Number	TMI-4111	Type a plus sign (+) inside this box	+

INVENTOR(S)/APPLICANT(S)

Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Cliff Eugene	Freifer	Farmington Hills, MI
David Cardon	Rich	Park City, UT
Donald E.	Waagen	Peoria, AZ

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Applicants	:	Mark David Parsons et al.
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For	:	A SYSTEM AND METHOD FOR HELPING TO DETERMINE THE CONDITION OF ABNORMAL TISSUE
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Respectfully submitted,

Gary J. Pitzer
Reg. No. 39,944

TAROLLI, SUNDHEIM, COVELL,
TUMMINO & SZABO L.L.P.
1111 Leader Building
526 Superior Avenue
Cleveland, Ohio 44114-1400
Phone: (216) 621-2234
Fax: (216) 621-4072

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A SYSTEM AND METHOD FOR HELPING TO DETERMINE THE CONDITION OF ABNORMAL TISSUE

Technical Field

The present invention is directed to a method and system for helping to determine the presence of abnormal tissue and, more particularly, to a system and method for helping to determine the condition of abnormal tissue.

Background of the Invention

Medical thermal imaging is a non-invasive diagnostic technique in which changes in skin surface temperature are quantified. There are several clinical uses for thermal imaging. For example, thermal imaging may be used to determine the extent of a previously diagnosed injury or condition, to detect an internal condition, such as cancer, or to monitor the healing process of a patient.

One particular use of thermal imaging relates to the breast cancer. Cancerous areas have abnormal capillary structure, which usually results in warmer skin surface temperatures adjacent or near the cancerous region. Such

temperature characteristics may be detected by thermal imaging.

Unlike some conventional methods of diagnosis, thermal imaging requires no contact with the body and there is no exposure to radiation as with mammography. Conventional mammography, through an application of radiation, detects and/or measure the structural or anatomical lesions which may be present within the breast.

Historically, temperature sensing devices, such as for breast thermography, have been controversial in the medical community as yielding unacceptably high false-negative results. In general, the thermographic data for such studies required a subjective interpretation based solely on qualitative assessments by the examiner. Such early test results were not easily reproducible nor quantifiable.

Summary of the Invention

The present invention is directed to a thermal imaging system. The system includes a thermal sensing device which is operative to measure thermal radiation from an object. The thermal sensing device provides an image signal indicative of the measured thermal radiation of the object. The image signal defines a plurality of image frames of the object over a time period. Each of

the frames has a plurality of pixels which correspond to a thermal condition of a part of the object. A processor, which is responsive to the image signal, determines a cooling response for at least a substantial portion of the pixels over the time period. The processor is operative to determine at least one feature for each cooling response, each feature having a value indicative of part of each respective cooling response. The processor also is operative to determine a likelihood value for each feature value, with each likelihood value being indicative of the likelihood of malignancy for a part of the object.

The present invention also is directed to a method for helping to differentiate between benign and malignant lesions. The method includes obtaining a plurality of consecutive digital thermal image frames of at least part of an object over a time period, with each of the frames having a plurality of pixels. A cooling response is determined for each of the plurality of pixels. A value for at least one feature of each cooling response is determined, with each feature value being indicative of part of the respective cooling response. Each feature value is applied to a predetermined classifier and a likelihood value for each feature value is determined.

Each likelihood value is indicative of the likelihood of malignancy for a part of the object.

Brief Description of the Drawings

The foregoing and other features of the present invention will become more apparent to one skilled in the art upon consideration of the following description of a preferred embodiment of the present invention and the accompanying drawings in which:

Fig. 1 is a schematic representation of a system in accordance with a preferred embodiment of the present invention;

Fig. 2 is a graphical representation of a first characteristic of data acquired in accordance with the present invention;

Fig. 3 is a graphical representation of a second characteristic of data acquired in accordance with the present invention;

Fig. 4 is graphical representation of a third characteristic of data acquired in accordance with the present invention; and

Fig. 5 is a flow diagram illustrating a process in accordance with a preferred embodiment of the present invention.

Description of a Preferred Embodiment

Fig. 1 illustrates a preferred embodiment of a thermal imaging system 10 in accordance with the present invention. The system 10 includes a thermal sensor 12 which is operative to measure the amount of thermal radiation, suitably including both conductive and convective heat, emitted from an object, such as the skin surface of a breast 14. The thermal sensor 12, an infrared camera, provides an image signal 16 to a microprocessor 18. The image signal 16 is indicative of the measured thermal radiation emitted from the breast 14.

The infrared camera preferably is a conventional digital infrared camera. Because the details of such cameras are well known in the art, their specifics will not be described herein. It will be apparent to those skilled in the art that method of data analysis algorithm described below should be tailored according to the specifications of the camera being used. Preferably, the images are acquired in the infrared wavelength range, suitably from about eight micrometers to about twelve micrometers.

The image signal 16 defines a plurality of consecutive image frames of the breast 14 taken over a period of time. Each of the image frames has a plurality

of pixels, with each pixel corresponding to a thermal condition of essentially the same part of the breast 14 in each of the consecutive image frames. For example, each image frame may have a pixel resolution of about 280 X 288 pixels per frame, suitably covering a 20° X 30° field of view of the breast surface. It will be appreciated by those skilled that the term pixel as used herein may correspond to a single picture element, based on the camera's resolution, or a grouping of a plurality of such picture elements. In any event, each pixel corresponds to the same region of the breast in each of the image frames.

Each image frame includes at least one region of interest which is centered on a lesion located within the breast 14. The location of the lesion may conveniently be detected, for example, based on a recent mammogram, ultrasound imaging, a self-examination, or based on any other reliable localization techniques. The region of interest may be rectangular, suitably about the size of a standard breast quadrant.

The image signal 16 defines an image set consisting of a plurality of image frames of the breast 14. Preferably, each of the image frames is acquired and stored in suitable memory 20 associated with the thermal sensor 12 and/or the microprocessor 18.

The microprocessor 18 may be a personal computer, an integrated circuit, a plurality of discrete components and/or a combination of discrete components and integrated circuits configured to control the imaging process.

Preferably, the acquired image data is forwarded to a remotely located central data processing station 22 by any suitable means of data transmission. The central processing station 22 may, for example, be located in the same or a different facility from where the image sensor 12 is located. The central processing station 22 has a microprocessor which performs analysis of the image data in accordance with the present invention. Alternatively, the microprocessor 18 may be programmed to perform the data analysis. It will be appreciated by those skilled in the art that the data analysis is computational intensive.

The microprocessor 18 also is electrically connected with a source of cooling air 24 which provides a cooling challenge to the object, such as the breast 14, which is to be imaged. The microprocessor 18 provides a control signal 26 to a control switch 28 of the source of cooling air 24. As shown in Fig. 1, a plurality of conduits 30, 32, 34, and 36 extend from the source of cooling air 24 to locations adjacent to where the breast 14 is positioned. Each of the conduits 30, 32, 34, and 36 provides cooling

air, indicated at arrows 38, uniformly onto the breast 14. The conduits 22, 24, 26 and 28 may be adjustable to ensure uniform cooling of the breast 14. Preferably, the cooling challenge is provided at about 15°C below ambient temperature to cool the skin tissue of the breast 14.

Preferably, a patient lies prone upon a table 40 with the patient's breast 14 extending through a corresponding aperture formed in the table 40. As the surface of the breast is cooled by the chilled air 38, a plurality of mirrors 42, 43 reflect thermal radiation, indicated at 44, from the breast to a lower mirror 46. While the view of Fig. 1 illustrates only two such mirrors 42, 43, preferably a greater number of mirrors are oriented in a conical array about the breast 14 to reflect the thermal radiation from the breast. The lower mirror 46, in turn, reflects the thermal radiation, indicated at 48, to the thermal sensor 12.

A preferred embodiment of a functional thermal imaging apparatus is described in co-pending U.S. application no. 08/864,752, which is assigned to Thermal Medical Imaging, Inc. and incorporated herein by reference.

The image set for the breast 14 suitably includes about 100 image frames. For example, the image frames may

be acquired by the thermal sensor 12 so that the microprocessor 18 acquires about one image frame every two seconds. A first portion of the frames acquired, such as about the first 10 to 20 frames, form a baseline equilibrium period prior to applying the cooling challenge. After the first 10 to 20 frames are obtained, the microprocessor 18 provides the control signal 26 to activate the source of cooling air 24 to initiate the cooling challenge. This typically occurs about 30 seconds following the inception of the image scan.

As the cooling challenge is applied to the breast 14, the thermal sensor 12 continues to provide the image signal 16 to the microprocessor 18 indicative of the thermal radiation emitted from the breast 14. The image set represents the temperature of the surface of the breast 14 for about 100 consecutive frames. The image set spans a time interval which includes both for a period before and during application of the cooling challenge.

Because the individual pixels of each of the plurality of image frames will be analyzed to help differentiate between malignant and benign tissue, it is important that each pixel of each of the consecutive image frames corresponds to substantially the same part of the breast 14. Accordingly, the breast 14 must remain

essentially stationary during the data acquisition phase. The above-incorporated patent application advantageously provides a thermal imaging apparatus designed to help minimize movement of the breast 14. In general, movement of the breast 14 is minimized by controlling inflation of an inflatable cushion 49 by an inflator system 51. The inflatable cushion 49 is controlled to counteract movement of the breast 14 as the patient breathes. This enables the sensor 12 to acquire good registration between successive thermal images of the breast 14.

The microprocessor 18 may provide a signal 50 to an output device 52, such as a conventional video display device. Alternatively, or in addition to a video display device, the output device 52 may include a printer or other device capable of displaying a representations of the acquired image data and/or results of the analysis.

An input control device 58 also is electrically connected with the microprocessor 18. The input control device 58 may be a conventional computer keyboard, a voice recognition input device, or any suitable input device for inputting control instructions to the microprocessor 18.

Upon completing the data acquisition phase, in which the image set for the breast 14 is obtained, a pixel-by-pixel analysis of each of the image frames is performed.

Preferably, the analysis is performed by a super computer, which may be located at the central processing station 22, as described above. Accordingly, the microprocessor 18 transmits the acquired image set to the central station 22 for analysis. Alternatively, the image set may be analyzed locally by the microprocessor 18.

The data analysis includes determining a cooling response for each pixel. The cooling response for each pixel contains quantitative features indicative of various thermal characteristics of each pixel over the data acquisition period defined by the image set. Because the breast remains essentially stationary during the data acquisition phase, each pixel represents the amount of thermal radiation emitted from a particular part of the breast 14 in each of the consecutive image frames. Therefore, the cooling response for each pixel corresponds to the temperature characteristics of a specific location of the surface of the breast 14.

The cooling response for each pixel is quantified based upon one or more cooling models. Each cooling model quantifies the cooling response for each pixel as a function of the temperature characteristics for each pixel over the time period defined by the image set. This is accomplished through feature extraction, in which values

for each of the features of each cooling response are derived from the image set. The feature values are determined by selecting the values so that each cooling model fits a curve based on each of the cooling responses.

A preferred cooling model is based on a double-exponential decay of the form:

$$T = T_o + T_1(1 - e^{\alpha_1 t}) + T_2(1 - e^{\alpha_2 t}) \qquad \text{(Eq. 1)}$$

where

T_o = initial temperature data (°C);

T_1 = average temperature from T_o to the thermal stress temperature (°C);

α_1 = rate of thermal response from T_o to the post thermal stress temperature (1/seconds);

T_2 = average temperature from T_o to the thermal stress temperature. (°C); and

α_2 = rate of thermal response from T_o to the post thermal stress temperature. (1/seconds)

The T_o value corresponds to the average temperature data in the image frames prior to initiating temperature challenge. The T_1 and α_1 coefficients correspond to initial patient responses. While the T_2 and α_2 coefficients correspond to long term temperature responses.

The double exponential of Eq. 1 may be simplified by approximating the second exponential by the first term in

its series expansion. Accordingly, the cooling model of Eq. 1 may be reduced to:

$$T = T_o - \delta(1 - e^{\alpha t}) - \beta t \qquad \text{(Eq. 2)}$$

where:

T_o = initial temperature before initiation of cooling challenge (°C);

δ = magnitude of rapid cooling component during cooling challenge(°C);

α = rate of rapid cooling component during cooling challenge(1/seconds); and

β = rate of slow cooling component during cooling challenge(°C/seconds).

Fig. 2 illustrates a typical cooling response for a single pixel over a cooling time period corresponding to about one hundred image frames. The regular cooling response is indicated at R. The double exponential decay model of equations one and two are used to model the portion of the image data acquired after initiation of the cooling challenge.

One particular model based on Eq. 2 is a regular model. Features of each cooling response for the regular model may be determined using least-squares regression applied directly to each pixel of the temperature data. The regular features thus include the coefficients (T_o, δ, α, and β) of Eq. 2.

The pre-cooling data, which includes about the first 10-20 frames, is analyzed using linear regression. This results in two additional features, namely a slope and intercept. The slope corresponds to the rate of the temperature change during the time before initiation of the cooling challenge and the intercept corresponds to the initial temperature when the test was initiated. The slope and the intercept in combination with T_o, ∞, α and β comprise six features for analyzing the cooling response of each pixel.

Another model, which may be used to produce quantified features for the cooling response, is referred to as a differential model. The features of this model may be determined by computing differential temperature data. The differential temperature data may be calculated by subtracting from the temperature value of each pixel the mean temperature for all pixels in the same frame (i.e., at the same instant in time). The differential features may be obtained by applying least-squares regression to the differential temperature data, as described above for the regular model.

A differential response for a single pixel is indicated as D in Fig. 3. Similar to the regular features,

the differential model produces six features, which include:

T_{od} = initial temperature before initiation of cooling challenge (°C);

δ_d = magnitude of rapid cooling component during cooling challenge(°C);

α_d = rate of rapid cooling component during cooling challenge (1/seconds);

β_d = rate of slow cooling component during cooling challenge(°C/seconds);

$intercept_d$ = the initial differential temperature when the test is initiated (°C); and

$slope_d$ = the rate of differential temperature change before initiation of the cooling challenge (°C/seconds).

Another model which may be used to provide features indicative of the temperature characteristics of each pixel is a simple differential model. This approach does not require non-linear regression, as do the regular and differential models. The simple differential features are local averages of the differential temperature at three points in the time during the cooling challenge.

For example, a differential feature may include: *T + 10*, which corresponds to the average differential temperature 10 frames (about 20 seconds), after cooling was initiated; *T + 50*, which corresponds to the average differential temperature 50 frames (about 100 seconds)

after cooling was initiated; and *final*, which corresponds to the average differential temperature at the end of the cooling challenge. Fig. 4 illustrates the same differential response as illustrated in Fig. 3, but with the simple differential features indicated.

Each of the 15 features for each model preferably is determined for the cooling response of each pixel. Individual features are selected and combined into groups of one or more features. This provides a plurality of possible feature combinations. It will be appreciated that combining more features for analysis results in a greater degree of freedom. The use of about three or four selected features typically should suffice.

In certain circumstances, certain differential features may provide better results than regular features. This is because the differential features provide a greater level of independence from patient-to-patient variations in the cooling response than the regular features. These variations may not contain statistically significant diagnostic information. In addition, the differential features may be less affected by variations in the accuracy of the thermal sensor 12 than the regular features.

The initial temperature value (T_o, T_{od}) and the magnitude of the cooling response (δ, δ_d and β, β_d) are important features in determining a likelihood of malignancy. The features selected for analysis, therefore, preferably include at least the initial temperature (T_o; T_{od}) and/or a measure of the cooling magnitude (δ, δ_d; β, β_d). The selected features preferably correspond to the initial temperature and magnitude of the cooling response features for the differential model, namely T_{od} , δ_d, and β_d. The set of feature values determined for each of the cooling responses collectively define a vector of feature values.

The feature vector is applied to a predetermined classifier, such as a Bayesian Classifier. In general, a particular classifier is determined, or trained, based on a statistical analysis of selected feature values of the cooling responses of lesions of known pathology. Each classifier is specifically designed to correspond to a selected feature or combination of features. Accordingly, several classifiers may be derived for analyzing different respective selected features of the cooling responses of an image set.

In order to derive a classifier, an expectation maximization technique is used to generate a description

of the probability distribution of each class condition, namely malignant and benign, for each cooling response of numerous image sets of known pathology. The description is a linear combination of n dimensional Gaussian distributions, where n is the number of selected features for that classifier.

In the preferred embodiment, a Bayesian classifier is selected to determine a likelihood of malignancy for the selected feature vector. Preferably, the classifier has a good performance at high sensitivity for its ROC curve. Bayesian classifiers and their application to statistical pattern recognition are described in a publication entitled "Statistical Pattern Recognition," second edition, authored by Keinosuke Fukunaga, and published by Academic Press (1990), which publication is incorporated herein by reference.

The Bayesian classifier is applied to a left-out sample to determine a log likelihood ratio (LLR):

$$LLR = \ln\left(\frac{Pmalignant(f)}{Pbenign(f)}\right) \qquad \text{(Eq. 3)}$$

where f is the vector of feature values selected from the cooling response models.

The LLR output value provides a likelihood value which is indicative of whether each pixel corresponds to a

part of the breast that is malignant or benign. A higher LLR value indicates a greater likelihood of malignancy, and a lower LLR value indicates a greater likelihood of benignancy.

A set of LLR output values for the cooling response of each pixel is determined. The set of LLR output values may then be processed, such as by the microprocessor 18 or a suitable computer at the central station 22. The set of LLR values may be used to provide a representation of likelihood values corresponding to a breast. The data preferably provides a pixel-by-pixel representation of the likelihood values. The set of likelihood values, such as provided by the pixel-by-pixel representation, may be interpreted by a radiologist or other clinician. This advantageously helps a radiologist differentiate between malignant and benign lesions, thereby reducing the number of unnecessary biopsies.

A method for helping to differentiate between benign and malignant lesions in accordance with the present invention is diagrammed in Fig. 5. The process begins (100) with the microprocessor 18 being initialized, in which internal memories, flags, initial conditions, etc., are set to initial values. Prior to initiating the cooling challenge, an initial set of image frames of the

test object, such as the breast 14 (Fig. 1), are obtained (102).

The microprocessor 18 then activates the source of cooling air 24 to initiate the cooling challenge (104). At this time, a counter or timer is initialized (106) so that a desired number of image frames, suitably about 100 frames, are acquired. The microprocessor 18 acquires thermal image frames of the breast 14 (108) at a predetermined rate, such as about one frame every two seconds.

A determination is made whether the desired number of image frames have been obtained (110). If the desired number of frames has not been acquired, the process returns to step 108 and additional image frames are obtained.

Once the desired number of image frames are acquired, the image set is stored in appropriate memory 20. The microprocessor 18 or other computer device, such as a supercomputer at the central processing station 22, determines a cooling response (112) for each pixel of the image set. As stated above, a plurality of features are determined for each cooling response, such as the various features for the different cooling models. Values for the features of each cooling response may be quantified

according to Eqs. 1 or 2 (114) for the cooling models described above. A feature or combination of such selected features are selected (115) from the feature values determined for each cooling response of the image set. The feature values of the selected feature or features of each cooling response collectively define a feature vector, which is a vector of selected feature values for the image set.

A predetermined classifier is selected (116) to correspond to the features which were selected. The classifier, for example, is based upon a statistical analysis of the cooling response corresponding to the selected features for lesions of known pathology. The feature vector is applied to the classifier (118).

Next, a likelihood value is determined for each selected feature combination of each pixel (120). The likelihood value is indicative of the likelihood of malignancy based on the value of the selected feature or features for each pixel. The set of likelihood values for the feature vector are stored in suitable memory (122) associated with the computer which performed the analysis.

Where the analysis is performed at a central station, the results, which include the LLR values for each pixel, may be transmitted to a radiologist or other clinician for

interpretation. The results provide an indication of whether a biopsy should be performed, such as where there is a high likelihood of malignancy. If desired, the results of the analysis may be provided to a suitable output device 46 (124) for evaluation by a radiologist or other suitable clinician.

In view of the foregoing description, the system and method in accordance with the present invention advantageously helps a practitioner to discriminate between malignant and benign lesions. The system and process provide a determination of the likelihood of malignancy based on physiological components of the breast, as detected by digital thermal imaging. It also will be appreciated by those skilled in the art that the system and method of the present invention provide a useful adjunct to ultrasound and mammography.

From the above description of the invention, those skilled in the art will perceive improvements, changes and modifications. Such improvements, changes and modifications within the skill of the art are intended to be covered by the appended claims.

Having described the invention, the following is claimed:

1. A thermal imaging system comprising:

a thermal sensing device which is operative to measure thermal radiation of an object, said thermal sensing device providing an image signal indicative of the measured thermal radiation of the object, the image signal defining a plurality of consecutive image frames over a time period, each of the image frames having a plurality of pixels, each of the pixels being indicative of a thermal characteristic of a part of the object over the time period defined by the plurality of image frames, and

a processor, which is responsive to the image signal, said processor being operative to determine a cooling response for at least a substantial portion of each of the pixels of said plurality of image frames, said processor being operative to determine at least one thermal feature having a value indicative of part of the cooling response, said processor being operative to determine a likelihood value for each feature value of at least a substantial portion of the cooling responses, each likelihood value being indicative of the likelihood of malignancy for a part of the object.

2. A system as set forth in claim 1 wherein said processor is programmed with a classifier configured according to the at least one feature value of each cooling response, and said processor applying the at least one feature value of each of the cooling responses to the classifier to determine each of the likelihood values.

3. A system as set forth in claim 1 wherein the at least one feature of each cooling response for said plurality of pixels further includes a plurality of features selected as a function of each cooling response.

4. A system as set forth in claim 3 wherein said plurality of features are selected to be indicative of an initial temperature value and a magnitude value of the cooling response over the time period.

5. A system as set forth in claim 1 wherein each cooling response defines a curve which varies exponentially as a function of the temperature of the object over the time period.

6. A system as set forth in claim 1 wherein said at least one feature is selected as a function of the curve which defines the cooling response.

7. A system as set forth in claim 1 wherein the cooling response for each of the plurality of pixels is quantified as

$$T=T_0 - \delta(1 - e^{\alpha t}) - \beta t$$

where T= temperature of the object,
δ= magnitude of rapid cooling component,
α= rate of rapid cooling component
t= time,
β= rate of slow cooling component, and
T_0 = initial temperature of object,

and the at least one feature comprises T_0, δ, α, β, or combinations thereof.

8. A thermal imaging system comprising:

a thermal sensing device which is operative to measure thermal radiation from an object, said thermal sensing device providing an image signal indicative of the measured thermal radiation of the object, the image signal defining a plurality of image frames of the object over a time period, each of the image frames having a plurality of pixels which correspond to a thermal condition of a part of the object over the time period, and

a processor, responsive to the image signal, determining a cooling response for at least a substantial portion of each of the pixels over the time period, said processor determining at least one feature having a value for each cooling response, the feature value being indicative of a part of the cooling response, said processor having a preprogrammed classifier selected to correspond to the at least one feature of each cooling response, said processor being operative to apply each feature value to the preprogrammed classifier to determine a likelihood value indicative of the likelihood of malignancy for a part of the object.

9. A system as set forth in claim 8 wherein said processor provides a set of likelihood values, each of the likelihood values corresponding to a different part of the object and differentiating between parts of the object having a higher likelihood value from parts having a lower likelihood value.

10. A system for helping to determine the condition of abnormal tissue of an object, said system comprising:

a memory which stores an image set formed of a plurality of image frames, each of said image frames

having a plurality of pixels indicative of a thermal characteristic of a part of the object in each of the plurality of image frames;

a processor electrically connected with said memory, said processor being operative to determine a cooling response for at least a substantial portion of each of said pixels of said plurality of image frames, said processor being operative to determine at least one feature having a value, the feature value being indicative of part of the cooling response, said processor being operative to determine a likelihood value for each feature value of the cooling responses, each likelihood value being indicative of the likelihood of malignancy for a part of the object corresponding to a pixel.

11. A method for helping to differentiate between benign and malignant lesions:

obtaining a thermal image of an object over a cooling time period;

digitizing the image into a plurality of image frames which define an image set, each of the image frames having a plurality of pixels;

storing the image set;

determining a cooling response for each of the plurality of pixels of the image set over the cooling time period based on the at least one thermal characteristic;

determining a value for at least one feature of each cooling response, the feature value being indicative of part of the cooling response;

applying each feature value to a predetermined classifier, the predetermined classifier being selected according to the at least one feature;

determining a likelihood value for each of the at least one feature values, each likelihood value being indicative of the likelihood of malignancy for a part of the object.

12. A method as set forth in claim 11 further including the step of providing a signal corresponding to each likelihood value, and displaying an diagnostic image of the object based on the signal, the diagnostic image having a plurality of pixels, each pixel of the diagnostic image being functionally related to a corresponding likelihood value.

Abstract

A set of thermal images, which define a plurality of image frames for a suspected tissue, are provided. Each image frame has a plurality of pixels, with each pixel providing a cooling response of a part of the tissue over a time period. The cooling response of each pixel has at least one feature which is analyzed to determine a likelihood of malignancy for the suspected tissue.

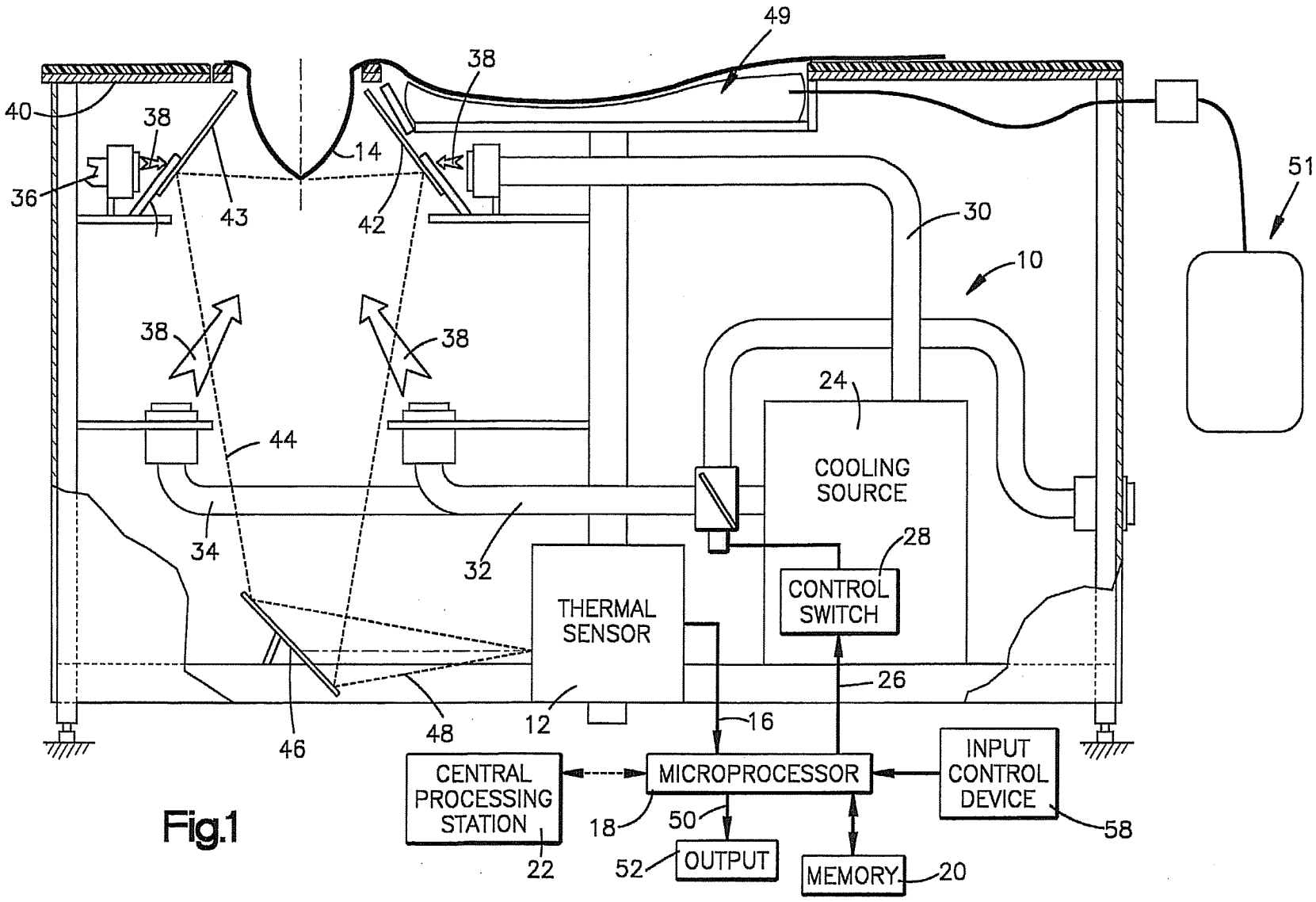

Fig.1

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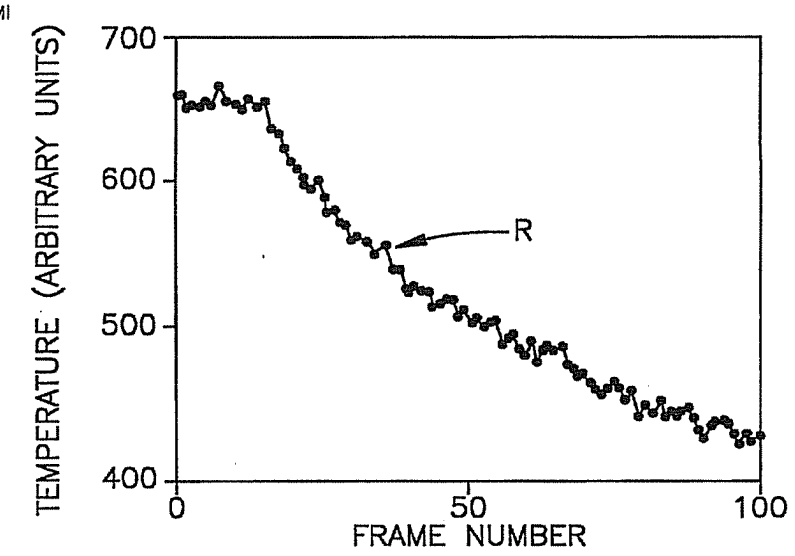

Fig.2

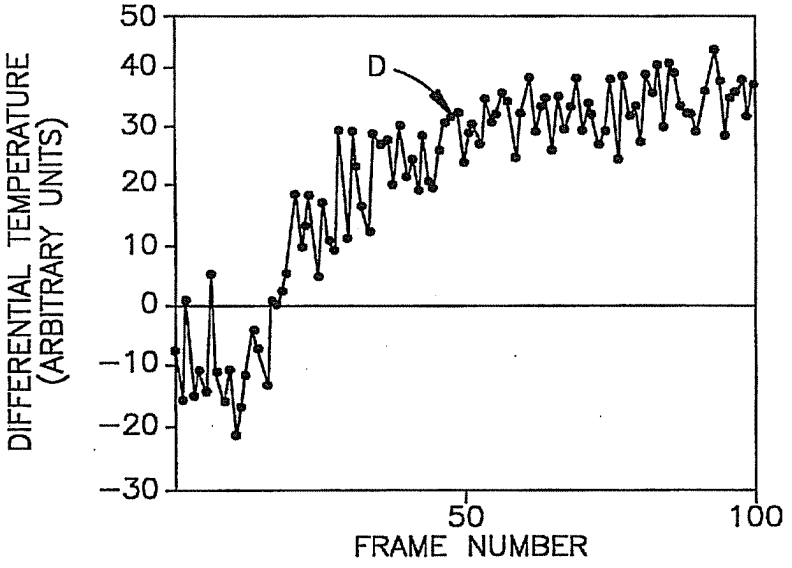

Fig.3

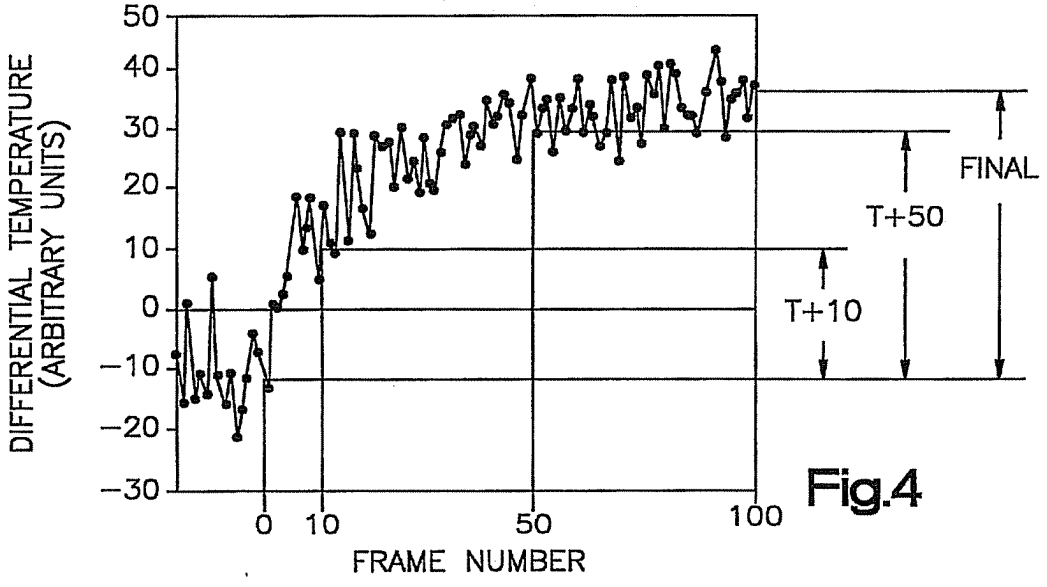

Fig.4

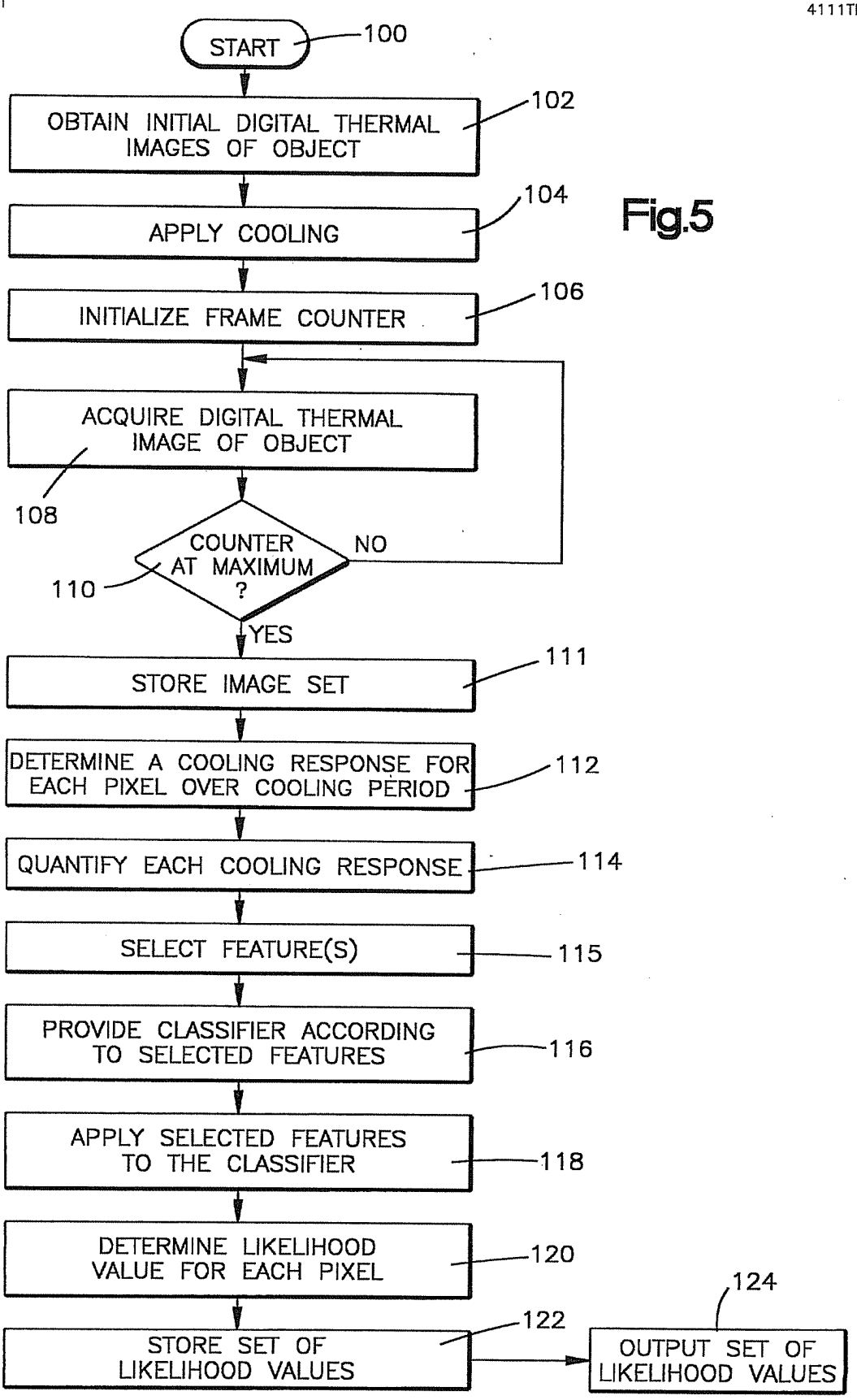

Fig.5

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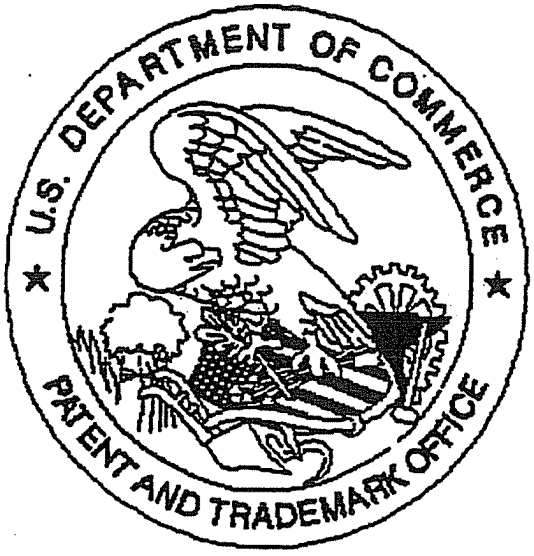

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